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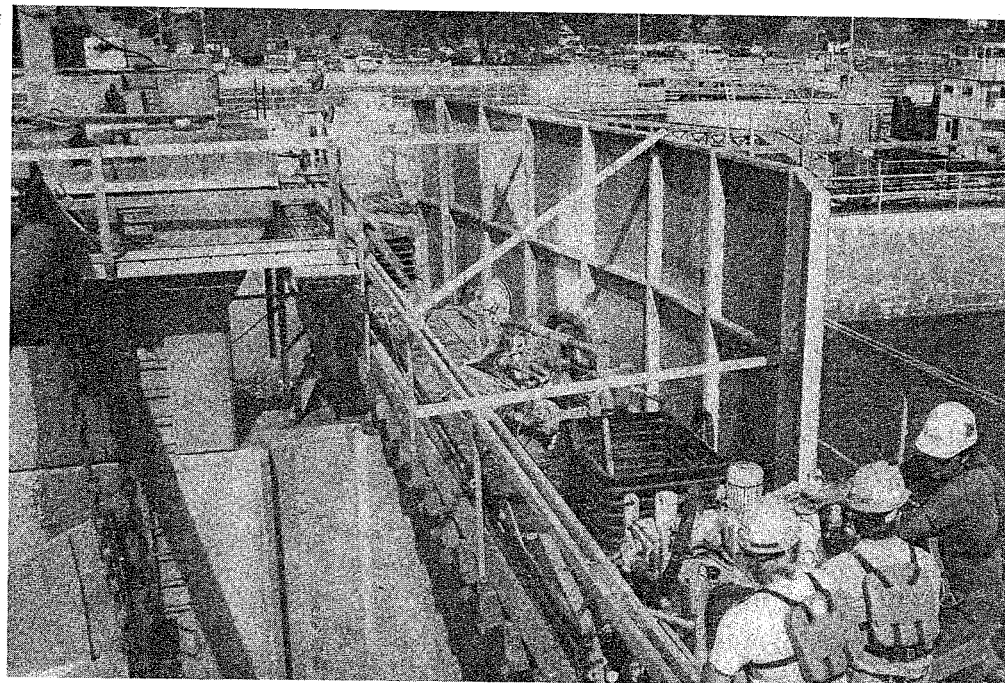
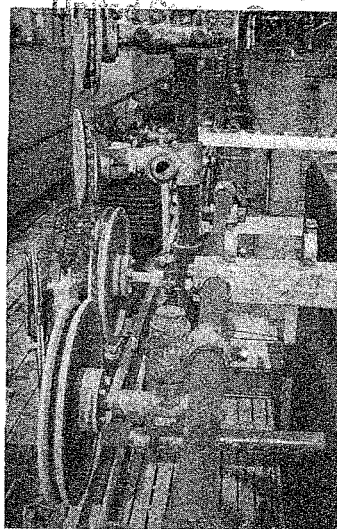
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Diamond wire saw set up on Lock No. 20, Mississippi River

Diamond Wire Cutting Used on Concrete at Marseilles Dam

by

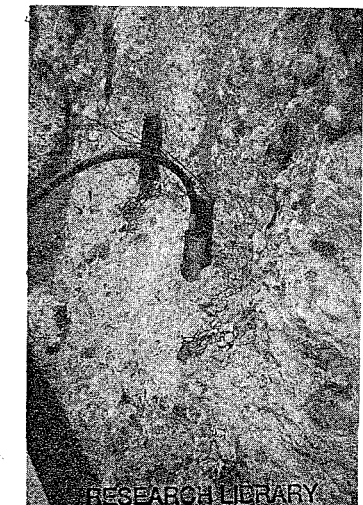
Michael W. Edwards

US Army Engineer District, Rock Island, Illinois

Today, as possibly never before, contractors are being caught between high labor costs and small profit margins. As a result, contractors must continually investigate innovative approaches to reduce the labor and time required for every phase of construction. As "owners," the Corps of Engineers must not only allow innovative approaches but must encourage them. This attitude is demonstrated by the innovative use of diamond wire cutting as a method of concrete removal at Marseilles Dam Rehabilitation, Stage I.

The dam renovation at Marseilles, Ill., on the Illinois Waterway consisted of the removal of eight nonsubmersible, counter-weighted tainter gates and their replacement with submersible, noncounter-weighted tainter gates. To accomplish this renovation, a major reconfiguration to both the spillways and gate piers was required. For the piers, work included the removal of 6- by 8- by 9-ft, 30-ton sections containing the trunnion anchorage.

The concrete in the piers, which was approximately 54 years old, had



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a compressive strength in excess of 8,000 psi. Aggregate in the concrete had a maximum size of 2-1/2 in., and well-rounded dolomite was the dominant portion of the coarse aggregate. Four 4-in.-diam trunnion anchors and numerous 2-1/2-in.-diam anchors extended through the cut.

Initially, the contractor had estimated the work would take 8 days and \$2,000 per pier using hand-held breakers and a boom-mounted breaker with a 250-ft-lb limit. However, after completing three of the piers, the removal was averaging 10 days and approximately \$7,000 per pier using five laborers and an equipment operator. The contractor recognized that without some improvements the resulting delay and cost could cause him to fall behind the approved schedule and reduce the potential for profits.

To correct the situation, the contractor proposed using diamond wire cutting, a removal technique traditionally used in stone quarries. In this method, a saw with a diamond, band-saw type blade that can be configured in numerous ways via idler wheels is used to cut the concrete. The blade's flexibility allows for vertical, horizontal, and angular cuts. The saw can be used in areas of difficult access and is not limited by depth of cut. Application of the system seems to be limited only by the imagination of the user.

The approval of the wire cutting required allowing the contractor to slightly deviate from the plans. The original plan was not to disturb the 4-in. trunnion anchors and to weld a plate to anchors as part of the trunnion system. A change allowed cutting the anchors, removing a small amount of concrete from around them and then welding the plate to them. This variance had no negative impact on the end product.



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The diamond wire cutting was subcontracted to a private firm. The equipment used on the job consisted of a 4-ft-cube, 1,200-lb power unit; a 3- by 4- by 8-ft, 1,400-lb saw; idler wheels; and a wire loop. The electrically driven (440 v, 50 amp) power unit supplied hydraulic flow to the saw motor. The saw was comprised of a flywheel, its motor, and a hydraulic stroke cylinder. The stroke cylinder positioned the flywheel to create the desired tension in the wire loop. Idler wheels were used to guide the wire and to direct the cut. The wire was a steel wire rope encased in a series of alternating beads and spacers (Fig. 1). The beads were steel with embedded diamonds, and the spacers were injected plastic sleeves. Two sizes of wire were used, a 3/8-in. wire that had beads with electroplated diamonds and a 1/2-in. wire that contained beads with impregnated diamonds. Beads with impregnated diamonds have a longer cutting life; however, they are more expensive and slower cutting (wires with plated diamonds and steel spring spacers seemed to be the subcontractor's preferred choice for a recent project).

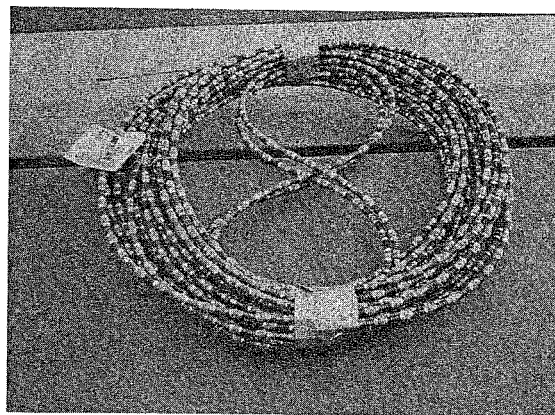


Figure 1. Saw wire, showing beads and spacers

Cutting at each pier started from a borehole to avoid overcutting. The borehole was drilled 2-1/2 in. in diam, even though only a 1-in. hole was needed. A 1/2-in.-diam wire was used to start the cut and was replaced with the 3/8-in. wire when the cut opening was reduced to near 3/8 in.

The general procedure used in making a cutout involved:

- Drilling boreholes across the pier at the bottom, upstream corner of a cutout;
- Setting up the saw and idler wheels;
- Inserting the diamond wire through a borehole;

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- Splicing the ends of the wire with a steel couple to complete the loop;
- Making the horizontal cut while placing steel wedges in the cut to maintain an opening as cutting proceeded;
- Relocating idler wheels, cutting and resplicing wire, and making the vertical cut, starting again at the borehole. A large crane was used to complete the removal.

Using the wire cutting method, and employing a technician, one laborer, and a crane operator, the subcontractor completed a pier every 3 days at a cost of \$6,500 per pier. The cost amounted to approximately \$63/sq ft of cut. The cutting rate was estimated to be between 10 and 15 sq ft/hr.

The work involving the removal of pier sections at Marseilles Dam was well suited for the diamond wire cutting technique for the following reasons:

- It could be employed in an area of difficult access and was not limited by depth of cut;
- It could be used to make a well-defined cutout without overcuts;
- It could be used to cut steel embedments without damaging or disturbing the portion of embedment and surrounding concrete that remained;
- It could be used to make cutouts in an expedient manner without increasing the cost.

Diamond wire cutting has since been used at Mississippi River Lock and Dam No. 21 and is presently being used at Mississippi River Lock and Dam No. 20 (Figs. 2-4).

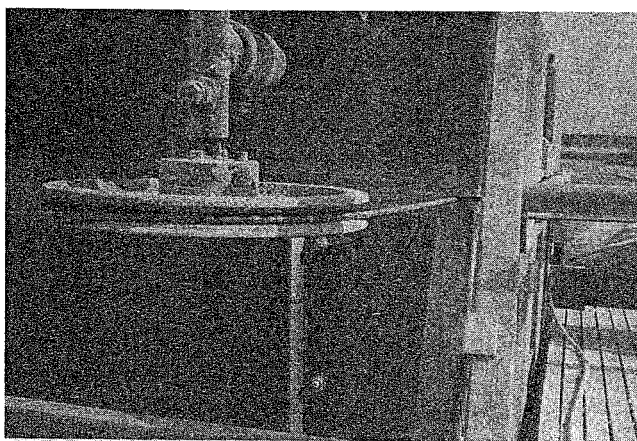


Figure 2. Starting a cut on Lock No. 20

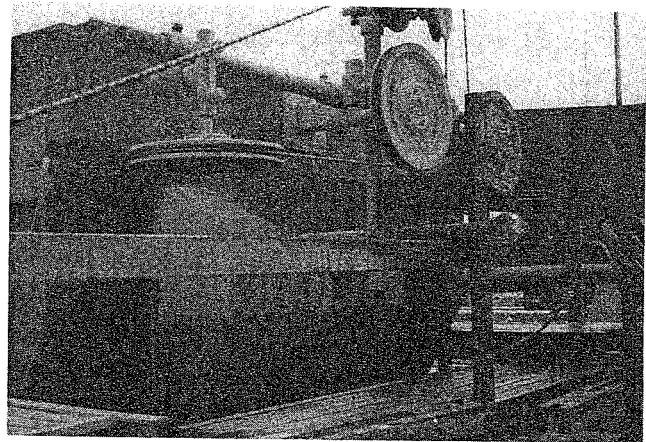


Figure 3. The saw has cut deeply into the concrete

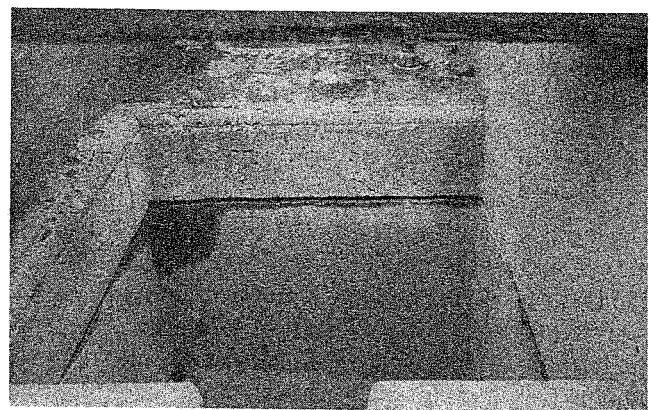


Figure 4. Completely sawed section on Lock No. 20

Although the cost of cutting will vary, depending on the percent of steel to be cut, type of aggregate, and size of job, diamond wire cutting may be a practical approach to concrete removal. It may not be practical for all projects, but there may be many where it presents a possible alternative to other techniques.

For more information contact Michael W. Edwards at (217) 222-0203.

Evaluation of Water Jet Blasting for Removal of Concrete From Lock Chamber Faces

by

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US Army Engineer Waterways Experiment

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In the USA, water jet blasting for concrete removal has been commercially available for about 5 years. Its primary application has been to remove deteriorated concrete from top horizontal surfaces of bridge and parking garage decks. What is attractive about the technique for deck rehabilitation work is that there is no microcracking in the surface after blasting, reinforcing steel is not damaged, and productivity exceeds that of the conventional removal method of jackhammering. The major drawback is the cost of water jet blasting, \$900 to \$2,500 per cu yd, depending on the size of job, depth of removal, and condition of the concrete to be removed.

In 1988, equipment for use on vertical surfaces was entering the market. This equipment was recognized to have potential for removal work at Corps lock wall rehabilitation projects. Particularly, it was thought to be useful for areas where explosive blasting was undesirable. This equipment was also recognized to have potential for limited underwater concrete removal. Coupled with an applicable resurfacing technique (i.e., the precast panel system), it is possible that water jet blasting could be used to eliminate the need for dewatering a lock. This would reduce overall rehabilitation cost.

DEMONSTRATION

In September 1988, as part of a feasibility study, water jet blasting equipment was demonstrated at the US Army Corps of Engineers Lock No. 2 on the Allegheny River near Pittsburgh, Pennsylvania. Concrete above and below the water was removed. The demonstration was to establish whether 12-in. and greater removal depths were reasonably attainable, as well as to evaluate the technique's potential for underwater removal.

The lock concrete was more than 50 years old. Its surfaces were deteriorated from cycles of freezing and thawing. The unconfined compressive strength of the concrete was estimated to be 5,600 psi based on 1987 tests of core samples taken from the wall where removal was to be performed. A

petrographic examination of the cores determined the concrete to be non-air-entrained and the aggregate to be a maximum 6-in., natural river gravel of mixed igneous, metamorphic, sand- and limestone composition.

The water jet system included a robot, two power packs, tanker truck, and a 170-cfm capacity air compressor. The electrically powered, hydraulically propelled robot was controlled with a programmed micro-computer. The robot's cutting head was equipped with a vertical track. Two water jet nozzles travelled up and down the track for a programmed number of times before the robot advanced. The mount for the nozzles had been modified to include a compressed air outlet. During underwater removal, air was blown between the concrete and water jet nozzles in an effort to provide a less dense medium and, thereby, maximize the impact velocity of the jetted water. Each nozzle had its own power pack. A pack consisted of a diesel engine, pump, and 1,100-gal water tank. Pumps operated at or near 17,000-psi pressure and provided a total combined flow of approximately 60 gpm. A commercial, 7,000-gal capacity tanker truck supplied potable water.

The robot was operated from a barge with power packs and water supply located on land. The operator had to wear hearing protection against the high levels of noise generated during the blasting operation.

The blasting produced feathered edges along the removal boundaries. Initially, ruts occurred at some locations within the removal area but were eliminated from following reaches by adjustments to cutting controls. Several form ties were encountered but did not significantly affect production. Removal depth was measured at points located on 1-ft intervals along the vertical profiles of the newly created surface. The depths for adjacent points sometimes varied several inches. This difference was caused by the varying depths of deterioration and the type aggregate in the affected surface. Soft aggregates eroded flush with the surface, and hard aggregates protruded with most of the paste eroded around them.

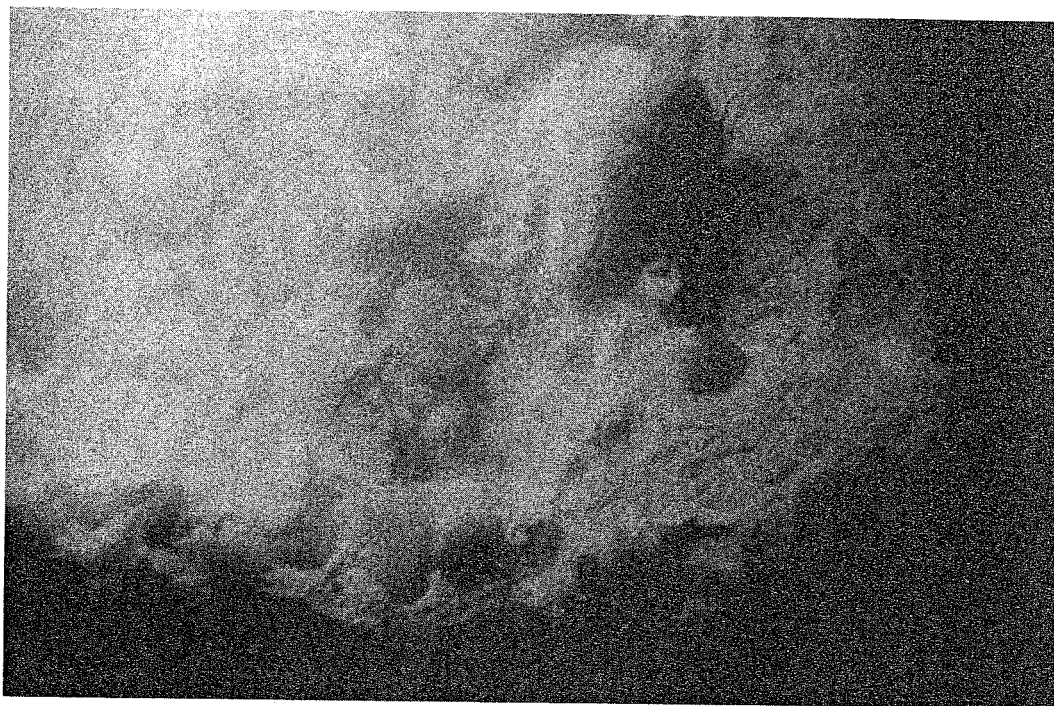


Figure 1. Results of underwater removal 4-ft below water surface

Water jet blasting above the waterline took approximately 3 hours with 0.7 cu yd of concrete removed. The average water demand was approximately 2,300 gal/hr of operation or 10,000 gal/cu yd of concrete removed. The average removal depth was 12 in.

The underwater operation took place during a 2-hr period with 0.3 cu yd of concrete removed between the pool elevation and 4 ft below (Fig. 1). Removal depth averaged 4.5 in. Underwater, the removal rate was approximately 35 percent less than that above water. It is suspected that the concrete below the waterline was sounder, primarily because it had been protected from cycles of freezing and thawing by the surrounding water and therefore was more difficult to remove. The underwater rate would have been somewhat less if the removal had continued to a 12-in. depth because of loss of cutting efficiency with depth.

FIELD APPLICATION

In June of 1989, water jet blasting was performed at US Army Corps of Engineers Dashiields Locks on the Ohio River near Pittsburgh, Pennsylvania, as part of ongoing rehabilitation work at the project. For the chamber face of the land wall, water jet blasting was selected to remove approximately 12,000 sq ft of concrete to a minimum depth of 12 in. within a 14-day period.

The 60-year-old concrete was deteriorated from cycles of freezing and thawing. Unconfined compressive strength of the sound concrete was estimated at 6,280 psi. A petrographic examination of the cores determined the concrete to be non-air-entrained and the aggregate to be a maximum 3-in., natural river gravel, the bulk of which was a sandstone with miscellaneous particles of quartzite, igneous rocks, conglomerate, and limestone.

The water jet system for this project consisted of a low-pressure filter system, power pack, and robot. The filter system transposed river water impounded in the chamber to potable water. The robot's distance from the chamber face was maintained by an optical system using two electric eyes and a stationary target at the end of the barge. The robot had been programmed for a single pass over the surface per advancement. Otherwise, the system was like the one used during the demonstration, except no compressed air outlet was provided.

Filter system and power pack were loaded on the barge deck. The robot was loaded on an elevated deck constructed along the edge of the barge (Fig. 2). The barge was maintained at a fixed distance from the wall by brackets constructed at the ends of the barge (Fig. 2). Blasting started near the upstream gate recess and proceeded downstream, removing a strip of concrete between the

horizontal armor at the top of the wall to approximately 3 ft below (Fig. 3). The blasting produced ragged edges along the removal boundaries. Removal depth was approximately 12 in., except at horizontal lift joints where the removal depth was around 17 in.

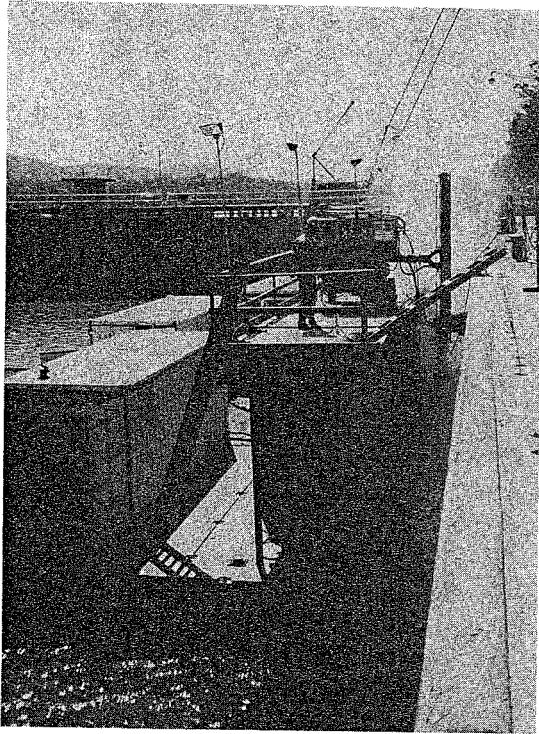


Figure 2. Water jet blasting of land wall chamber face

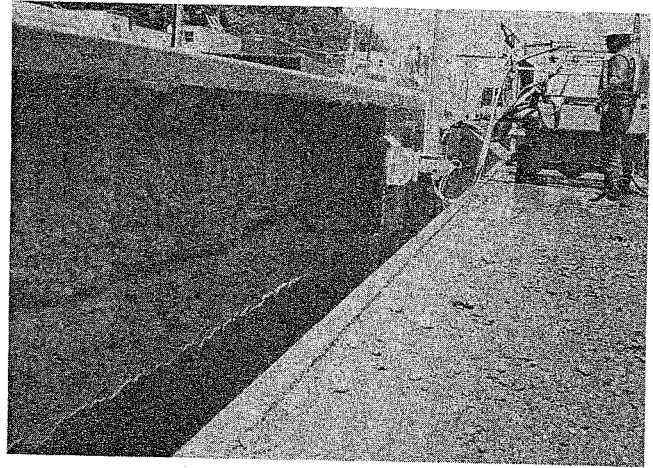


Figure 3. Removal strip

When the robot reached the end of the elevated deck, the barge was winched to a new position. The removal strip became wider as the dewatering of the chamber began and the water level dropped (Fig. 4). The water jet system was operated 24 hr a day using two shifts of three-men crews. The debris from the removal was contained for the most part as sediment of the impounded water in the chamber; however, some of the suspended debris entered the river during dewatering of the chamber.

Noted safety problems were high noise levels (100 db at 50 ft and 92 db at 110 ft) and flyrock. Some aggregate was propelled 40 ft or more. An inspection of the flexible flyrock shields at the end

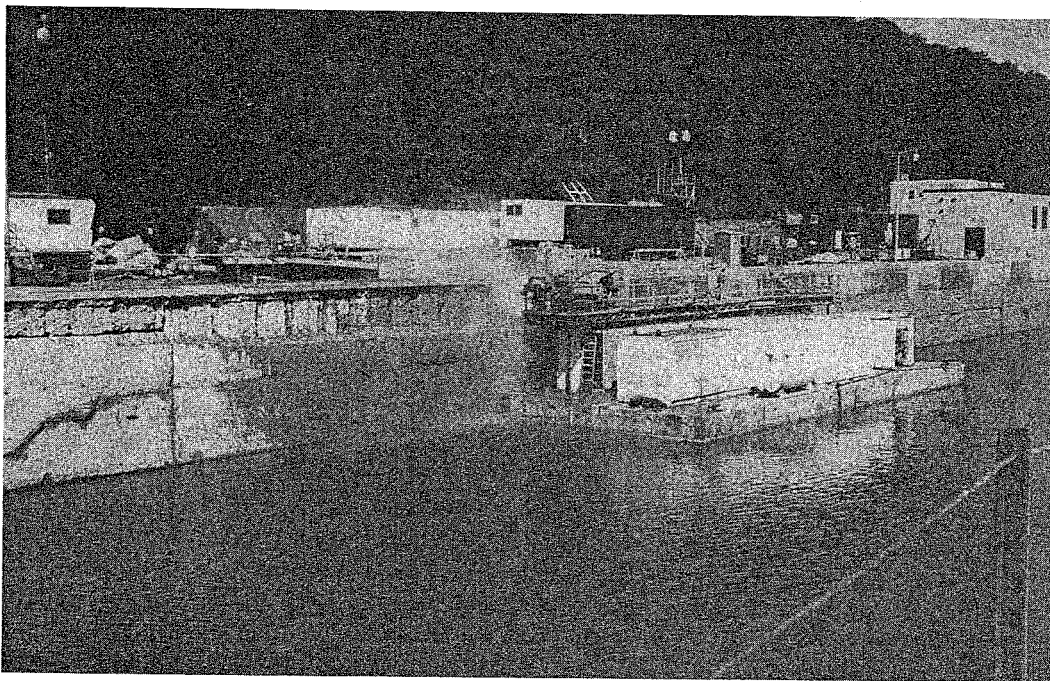


Figure 4. Water jet blasting as viewed from across lock

of the job showed the upstream and downstream shields had lost approximately 50 percent of their area.

The use of the system was terminated after 10 days because of an unacceptable removal rate. There were several break downs of equipment that delayed the removal effort and reduced the water jet's performance. The overall performance included an average removal rate of approximately 0.6 cu yd/hr and a 1-day peak rate of 0.8 cu yd/hr.

The manufacturer's representative indicated that the efficiency of the water jet blasting could be improved by modifying the cutter head design to allow the nozzle to move into the cut as the removal depth increased. It was estimated that this change could provide a removal rate of around 3 cu yd/hr. This estimate was based on the equipment's performance in Europe where rates of around 3.5 cu yd/hr were stated for 6-in. removal depths. The design change is expected to be implemented in the spring of 1990.

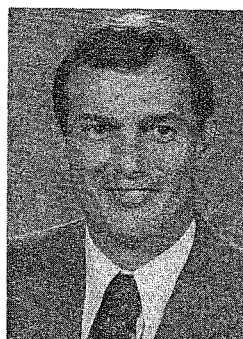
CONCLUSIONS

As employed, water jet blasting is not expedient enough to be competitive with conventional explosive blasting nor the newly employed rock jack technique for lock wall rehabilitation work. Even if an acceptable removal rate can be achieved through design changes, the cost effectiveness of water jet blasting will yet have to be proven. Cost saving potential still exists for using water jet blasting to eliminate dewatering of locks. This removal method also has potential for removing deteriorated concrete from vertical and sloped faces of other types of water bound structures, such as guide, guard, and channel walls. It is estimated that for a 12-in. removal depth, a minimum of 300 cu yd of concrete would be necessary for the water jet to be economically competitive.

ENVIRONMENT

An evaluation to assess the effects of concrete removal debris entering a river, stream, or waterway is required prior to commencement of the removal. The effects will vary from project to project and will depend to a great extent on the size and environmental condition of the waterway and on the quantity of removal debris entering the waterway. At Lock No. 2 on the Allegheny River, water samples were taken. Test results showed only minor changes in the water quality as a result of the water jet blasting. The impact of these changes on the environment was considered negligible. For Dashields Locks, it was concluded prior to the commencement of the removal that no adverse affects were anticipated from any suspended solids that were the result of the water jet blasting and were introduced into the Ohio River during the dewatering of the lock. The aggregate portion of the concrete was considered to have no significant impact as it was a natural river gravel that was being returned to its place of origin.

For more information contact Roy L. Campbell, Sr., at (601) 634-2814.



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Mechanical Presplitting Technique Used in Removal of Concrete From Chamber Face at Dashields Lock

by

Doug Meley

US Army Engineer District, Pittsburgh

The Dashields Locks and Dam Project is located in the Corps of Engineers Pittsburgh District. The dam is the only fixed-crest dam still in service on the Ohio River. With a 10-ft lift, it provides a navigational pool for 7 miles upriver to Emsworth Locks and Dam near Pittsburgh, Pennsylvania. The locks consist of a 56-ft-wide by 360-ft-long river chamber, used primarily for small tows and pleasure boats, and a 110- by 600-ft land chamber (main chamber), used to pass an average of 550 commercial lockages every month.

Built in the late 1920's with non-air-entrained concrete, the locks are deteriorated by cycles of freezing and thawing and damaged from barge impact and abrasion. A comprehensive rehabilitation project was begun in 1987 to repair the concrete as well as the other deteriorated features of the lock.

The top of the lock walls are generally being repaired with a one-foot-thick overlay of new concrete on top of the existing concrete surface. Repairs to the vertical faces of the lock walls require removal and replacement of the deteriorated concrete.

Most of the vertical refacing was designated for the wall surfaces within the confines of the land chamber. The work had to be completed within the relatively short time spans that the main lock was allowed to be shut down to commercial traffic. It was therefore necessary for the contractor to devise a method of removing the approximately one-foot of deteriorated concrete quickly and efficiently.

On the Dashields project, the refacing work within the main lock chamber began with the removal of approximately 2,650 sq yds of vertical wall surface to a minimum depth of 12 in. The contract price for this removal work was \$190/sq yd. The individual wall sections were approximately 30 to 40 ft wide, corresponding to the individual lock wall monoliths, and 24 ft high, from the top of the lock wall to a point one-foot below lower pool level. The contract called for the work to be scheduled and completed during two separate

shutdowns and dewaterings of the land chamber. The first was a 45-day shutdown of the land chamber during the summer of 1988, and the second, a 60-day shutdown of the land chamber during the summer of 1989. The contractor scheduled approximately half of the refacing work for each shutdown.

Several methods of removal have been used by contractors in the past, including explosive blasting, jackhammers, and the use of expansive grout. Although the specifications permitted the use of the above methods in most locations, the contractor elected not to use these methods for various economic and risk considerations.

With the assistance of their parent company, located in Germany, the contractor chose to remove the concrete with hand-held rock jacks manufactured in West Germany. The assemblies, which were designed for use in a predrilled hole, consist of a cylindrically shaped jack approximately 14 in. long and 3-1/4 in. in diam with several lateral pistons exerting an outward force against a backer bar. The hydraulic pressure which operates the pistons is created by a portable hand pump which is connected to the jack (Fig. 1) by a 4- to 6-ft length of hydraulic hose (Fig. 2). The jack is inserted its entire length into a predrilled hole of a slightly larger diameter and pressure is then exerted against the backer bar. The jack develops a radial crack projecting several feet beyond the circumference of the hole (Fig. 3). The direction of the crack is controlled by the orientation of the pistons and the presence of adjacent line-drilled holes.

Preparatory work, which the contractor was able to complete prior to the shutdown, consisted of line drilling 3-1/2-in.-diam holes into the top surface, spaced approximately 12 in. apart, and set back approximately 15 in. from the chamber face. The holes were drilled the entire 24-ft depth of the removal section with a rotary-percussion, down-the-hole hammer. The drilling rate for the hammer was approximately 34-ft/hr. Shortly after dewatering, and



Figure 1. Rock jack connected to hydraulic hose



Figure 2. Worker using the portable handpump to create hydraulic pressure for rock jack

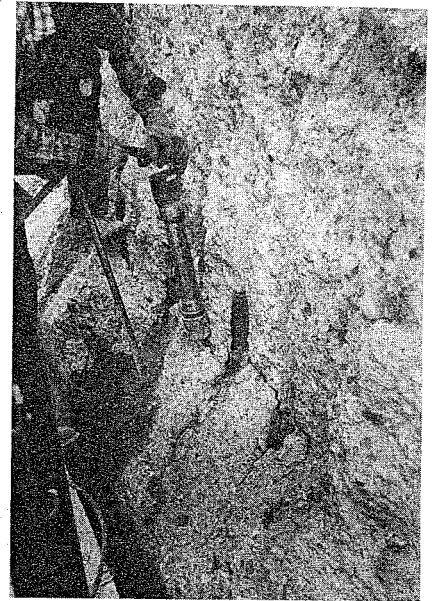


Figure 3. Radial crack developed with rock jack

prior to removal operations, the bottom edge of the removal section was saw cut to prevent over-breakage.

Most of the removal work was performed by laborers working from suspended scaffolds (Fig. 4). The concrete was removed in horizontal strips approximately 1 to 1-1/2 ft in height, working

from the top down. The rock jacks were generally used in tandem with the jacks inserted into every third hole.

In practice, a crack was initiated by pressurizing the first jack. As soon as the crack had propagated through the second and third holes, pressure was then applied to the second jack, causing

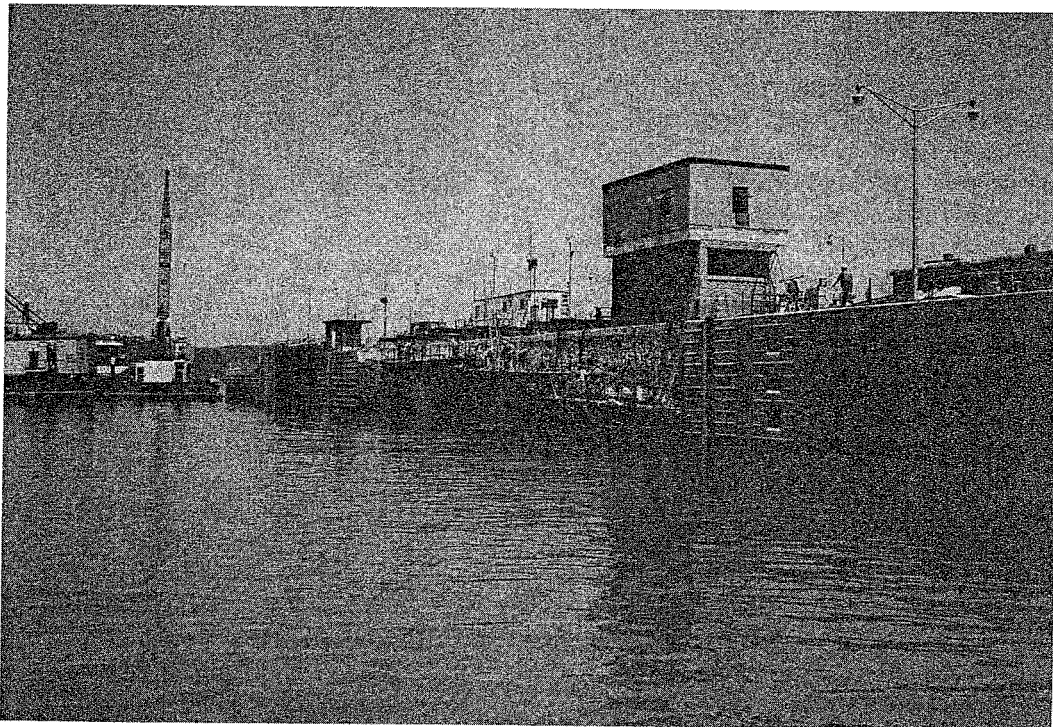


Figure 4. Suspended scaffolding at Dashields Lock and Dam Project

the crack to continue in zipper-like fashion. By using this method, the laborers were able to remove individual chunks of concrete as large as 1-1/2 by 6 ft. Final removal was accomplished with the aid of jack hammers and pry bars (Fig. 5).

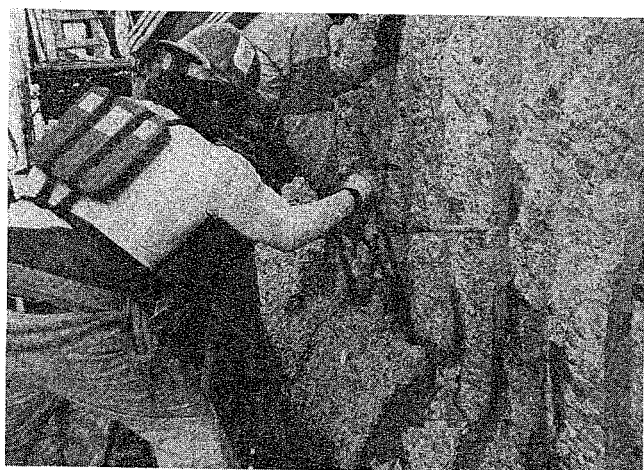


Figure 5. Pry bars aid in final removal of concrete

Since the individual concrete pieces most often fell onto or against the suspended scaffold, it was imperative that the scaffold be designed to resist these impact loads. It was also important that the laborers be tied-off independently from the scaffold and that foot protection be worn. Final disposition of the concrete to the chamber floor was achieved by allowing the concrete chunks to fall between the scaffold and the lock wall.

With this method, the contractor was able to achieve a removal rate of up to 500 to 600 sq ft of wall surface per 24-hr working day with two jacks. Higher production can be achieved by adding more jacks and work areas. As with any hydraulic equipment, it is extremely important to keep dirt from entering the hydraulic fluid. Dirt in the system causes the rubber seals on the pistons to score, thereby preventing sufficient buildup of pressure necessary to crack the concrete.

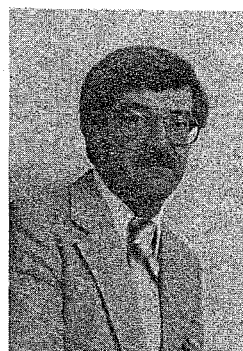
One operational deficiency is that the jack system has no way of retracting the pistons once they

have been extended. The reseating of the pistons can be done with a mechanical vise or manually. The work crew preferred the manual technique. The procedure is to release the pressure on the jack, lay the jack on the floor of the scaffold with the piston side down, and have the worker use his weight to reset the pistons.

The rock jacks have proved to be very successful in removing concrete efficiently and economically from the lock-wall faces at Dashields Locks. When considering this technique for similar work, a contractor will have to take into account the cost of drilling the 3-1/2-in.-diam boreholes and the number of splitters required to maintain an acceptable removal rate.

At Dashields Locks and Dam, water jet blasting was also used in an effort to increase the removal production rate. While the water-jet technique showed much promise, it was hampered by mechanical limitations on this particular project, and the rock jacks proved to be the more dependable method of removal.

For more information contact Doug Meley at (412) 457-9427.



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